Spent-Fuel Relocation Risk: What is the Central Issue?

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Abstract: A starting point for the resolution of the spent nuclear fuel dilemma nationwide will be to characterize the risks, both real and perceived, to the affected parties. The interested and affected parties include the electrical utilities, federal, state and local legislators and a variety of others. Acceptance of risk decisions by the broad spectrum of the parties will be critical to the implementation of any decision that is made. In this paper new ideas are presented for the risk characterization process for the relocation of spent nuclear fuel from reactor sites to a centralized interim storage facility. The risk is characterized in terms of potential and perceived risks to public health and safety in the case where the fuel is moved and in the case where it is not. Without eliminating any risks through analysis, it is seen that all risks, both real and perceived, can be summarized in terms of four distinct comparative risks that are distinct from one another by who the stakeholders are. From this it is seen that the central risk issue is one of whether to discount future transportation risks to present worth.

Introduction

Government and industry have devoted considerable resources to developing and applying techniques of risk analysis and risk characterization in order to make better informed and more trustworthy decisions about what to do with the nation's spent commercial nuclear fuel. The US government's long-term policy is towards disposing of spent nuclear fuel in a National Repository located at Yucca Mountain Nevada.[1] Yet the date for the repository opening to begin accepting spent nuclear fuel has slipped decades into the future and no clear decisions have been made about the status of the fuel in the interim.[2] Decision makers seem to be inundated with opposition at every juncture.

Two of the most obvious generic alternatives until a permanent solution to the nuclear waste problem are found are: (1) the spent fuel is stored at reactor sites until a repository becomes available (2) new storage capacity for spent fuel at one or more sites away from reactors is created and used. The first option may require packaging of the spent fuel in dry storage casks for a period of dry storage as spent fuel pools become full or obsolete. The second option requires development of a transportation infrastructure. This would require the near-term establishment of transportation routes, acquisition of trucks, trains and shipping casks and development of emergency preparedness plans at the state and local level.[3] Both storage methods are considered to be only an interim solution until a National Repository is available to accept the spent fuel. It may appear at first glance that there is no substantial differences among the two alternatives in the health, safety and environmental risks they pose, because the transportation of the spent fuel in the future is ususlly considered inevitable. The practical feasibility of dry-cask storage likely to be used in both cases has been proven.[4] In any case it is likely that even if away-from-reactor storage sites are made available, there would still be some spent fuel stored at reactors because some utilities may not choose to participate.

According to a recent National Academy of Sciences publication,[5] a reason why no decision has been made is in inadequacies in the techniques available for characterizing and analyzing risks to the public. Another reason for the failure has been because public participation and involvement has not been integrated into the risk characterization process from the start.[6]

In this paper a suggestion is made for changing the existing concepts of risk characterization in order to increase the likelihood of achieving a sound and acceptable decision with respect to the current spent nuclear fuel dilemma. The work presented here is directed toward informing choices and solving the problem. The risk characterization started here does not attempt to eliminate categories of risk through analysis. Rather, this characterization invites a risk analysis whose scope is determined by all perceived risk. The analysis and the following deliberation can be thought of as two complementary approaches to gaining knowledge about the problem and reaching agreement among people. The analysis should use rigorous, replicable methods, evaluated under the agreed protocols of an expert community—such as those of disciplines in the natural, social, or decision sciences, as well as mathematics, logic, and law—to arrive at answers to factual questions. Deliberation is any formal or informal process for communication and collective consideration of issues. Participants in deliberation discuss, ponder, exchange observations and views, reflect upon information and judgments concerning matters of mutual interest, and attempt to persuade each other. The risk characterization process should never be used as a means to stifle discussion.

Therefore the aim of this risk characterization is to describe a potentially hazardous situation in as accurate, thorough, and decision-relevant a manner as possible, addressing the significant concerns of the interested and affected parties, and to make this information understandable to the parties. The first step is to identify the stakeholders and their concerns. The second step is to systematize those concerns. Then the process of analysis and deliberation begins. This paper focuses on the first two steps but provides some conjecture about what the results of the analysis and deliberation shall be.

MRS History

When the Nuclear Waste Policy Act (NWPA) of 1982 was passed it formalized a national policy of geological disposal of spent nuclear fuel. The Federal government was to collect a fee of 1 mill/KWh from nuclear power generators or more to pay for the cost of storage and disposal and would accept spent fuel before the end of the century. Provisions for a Monitored Retrievable Storage (MRS) facility were included in the legislation because of a lack of storage volume at many reactor sites versus a growing volume of spent fuel.[7]

Attempts at siting a MRS facility were then been blocked by opposition at the state and federal level. Section 141(b) of the NWPA required the DOE to complete a detailed study of the need for and feasibility of an MRS and to submit to Congress on or before June 1, 1985 a proposal for construction and operation of one or more MRS facilities for receiving and storing spent nuclear fuel. Pursuant to this direction DOE completed a study on the need for an MRS and prepared a proposal to Congress for authorization to construct and operate a licensed MRS at Oak Ridge, Tennessee. The proposal called for an MRS facility to be licensed, constructed and operational at the Oak Ridge site by January 31, 1998.[8]

In 1986, the US district court in Tennessee granted an injunction to the State of Tennessee preventing submission of the MRS proposal to Congress. That decision was subsequently overturned. But by that time, Congress had stepped in to permanently block use of the Oak Ridge site for an MRS and to impose new restrictions with respect to siting an MRS facility. Congress also specified that the Yucca Mountain site in Nevada is the only site to be characterized as a site for a National Repository, and that no MRS shall be built in the state of Nevada.

The 1987 amendments to the NWPA established within the Executive branch the Office of the Nuclear Waste Negotiator, which was authorized for five years to attempt to locate and recommend for Congressional approval a voluntary candidate site for an MRS. Although the Negotiator's office was re-authorized for one more year after its original expiration date, it never achieved its purpose of finding a voluntary candidate site. The failure to site an MRS was due to the failure to find a State that would fund its own study for feasibility within its own boundaries. There was no provision for federal funding of such a study.

In late 1996, the DOE announced that it will not meet the deadline to accept spent fuel from the nation's nuclear utilities of January 31, 1998 that was specified in the 1987 amendments to the NWPA. In January 1997 a group of state regulators, attorneys general and nuclear utilities began to sue the DOE essentially for breach of contract.[9] In these cases so far the utilities have won the rulings.[10]

Stakeholder Identification

It may appear to an outside observer that there is no difference in the risk to the public *as a whole* between storage at reactor sites and storage at one or more away-from-reactor sites. Each of the storage options has strong political support and opposition. In general there is an array of perspectives. The residents living near reactors may fear for their health and safety and fear diminishing property values with the accumulation of spent fuel. Residents in states where an MRS may be located may have these similar fears.

In general, the greatest opposition to MRS siting comes from state governments. The strongest argument used is one of fairness, or equity-in-risk, i.e. it is unfair that we should bear the risk from another state's waste. Some have called this argument NIMBY, or "Not in My Back Yard," but this parody is not entirely accurate. Local governments may be divided or even in favor of the MRS because local communities may see themselves as benefiting economically.[11]

The people located along transportation routes between the current storage location and the new location may oppose the transportation based on the perceived risk from the potential for accidents that result in the release of radioactive material. Citizens and local governments may also fear that there may be some effects from direct radiation as the truck or train passes by. There is also the fear of undetected leakage of waste causing long-term illness. These stakeholders will usually agree that the spent fuel may have to be moved someday, somewhere, but may be suspicious of any plan to move the waste on a nearby route in the present time.[12]

A wider risk characterization must include threats of theft, sabotage and terrorist. All the citizens of the US and the world can be affected by terrorism and are therefore stakeholders. The idea that terrorist would posses nuclear weapons made from materials found in spent fuel has formed the basis for much discussion.[13] In some intellectual circles the threat of theft has been given the highest consideration in the risks from spent fuel.[14]

Finally there are anti-nuclear groups who see themselves as stakeholders in the relocation issue because of the broader policy issues that they feel are implied. These groups may oppose spent fuel relocation solely because of a desire to drive a final stake through the heart of nuclear energy prior to working towards any solution of the spent fuel dilemma.[15]

They may use the continued delays in the MRS and in the repository program to enhance their arguments against the continued operation of existing plants and to prevent the construction of new ones. These and other views[16] far outside the consensus represented by the NWPA of 1982 and its amendments are not discussed further in this paper.

The 15 Major Risks - a Starting Point

As a starting point for characterizing the risks, as opposed to analyzing the risks, we build an estimate of the stakeholders (public) views of the risks. In order to rationally discuss the risks, we will always consider the risk before relocation, during relocation (transportation), and after relocation to the new site. If something is considered by the public to be a risk, it is never discarded at this point because of analytical reasoning. In other words, what experts may call *perceived risks* are treated equally with *real risks* until the analysis is performed and the results of the analysis thoroughly explained to the public. Again, if the analysis is not believed by the public a decision cannot be made. The procedure is then repeated, treating the objections to the analysis as risks in themselves. These "risks" therefore form the basis for a second round of analysis.

Risk→ **↓ Context**	**Risk from sudden releases of radioactive material**	**Risk from long-term radioactive material releases**	**Risk from sudden exposure to direct radiation**	**Risk from long-term exposure to direct radiation**	**Risk of theft of nuclear materials**
current location	sudden release current location	long-term release current location	sudden direct exposure current location	long-term direct exposure current location	theft from current location
during transportation	sudden release during transportation	long-term release during transportation	sudden direct exposure during transportation	long-term direct exposure during transportation	theft during transportation
new location	sudden release new location	long-term release new location	sudden direct exposure new location	long-term direct exposure new location	theft from new location

Table 1. The 15 Major Risk/Context Combinations to be Considered in a Spent Fuel Relocation.

In Table 1 five risks to the public health and safety are considered, multiplied by the three situations (before, during and after relocation). These risks are broad categories only. The first two broad categories are risk from sudden releases of radioactive material to biosphere, and risk from long-term releases. These same two categories are then repeated, except for direct radiation. Finally there is the risk of theft. In the figure some more explicit text is included to state that sudden releases of radiation or radioactive material may occur as the result of accident or sabotage, and the release of radiation or radioactive material over long time periods is taken to occur in the absence of accident or sabotage.

One or more broad categories may appear to have been left-out. For example, a major concern often expressed about a potential interim storage site is that it will become a permanent site because of the belief that no long-term solution to the spent nuclear fuel problem will ever be found. The storage at a given site then is permanent unless relocated to another interim storage facility. The list, however, is meant to be inclusive of all time frames for storage. In other words, these risks are taken to be for all time in the future in the unlikely case that the fuel is never transported or altered again. It is more likely however, that if no National Repository is opened by the time the storage facility has reached obsolescence, the fuel would be moved to a new facility at that time. Alternatively, risks are for a period of, say, 30 years if interim storage is used only until the National Repository is opened 30 years from now.

Should the National Repository is to be considered as just another storage facility for these purposes? In other words, if the spent fuel is to be relocated to the Yucca Mountain site should we consider this in the same analysis as if the spent fuel is to be moved to a centralized interim storage facility? In a general case, the answer is yes, the same 15 risks apply, except that the 'new location' is the National Repository. However, the environment in which the waste is to be stored is quite different at a reactor in dry storage casks versus a mined geological repository. Additionally, the time frames differ because no one advocates non-retrievable storage at reactor sites, but disposal at Yucca Mountain is considered to be permanent. This "relocation analysis" would be more directly applicable to the hypothetical case where spent fuel already buried at Yucca Mountain were to be considered for retrieval and relocation to another site at some time in the future.

Sudden Radioactive Material Releases

Any given member of the public fears an "accident" that releases nuclear material into the environment. Material may be released into the air, the soil, an aquifer or a nearby body of water. All occurrences that are sudden and extraordinary in nature should be included in this general category. One example is if a cask were to become filled with water during a flood. If some of the fuel rod cladding had ruptured or cracked while in the reactor core, there could be some radiocesium present in the water surrounding the fuel. The cesium could leak into the ground and be carried away by percolating rainwater into an aquifer. Other potential initiators include tornadoes and airplane crashes.

The absolute value of the risk to the public, especially in the view of the public, is probably unquantifiable. For these types of risk the analysis of absolute risk would depend on knowledge of all possible initiating events, all possible defects in design and construction of the storage casks and storage facility, and all possible pathways for the material to reach the public. It is then presumed that if these things are known, additional design should be made to prevent the occurrence of the initiating event, the design flaw, or the pathway. After several design iterations some residual risk would exist from the unknown or the unknowable. That such a risk would exist to a small degree in fact may translate into a large risk from the public point of view.

The category is taken to include events that are the result of human error or sabotage, which is also largely unquantifiable. These events include acts of sabotage that are initiated by disgruntled plant personnel or by outside saboteurs. The quantification of such risk is nearly impossible. Rather, designers employ practices that can deter or prevent most such acts and to mitigate their consequences. In all cases, there remains the unknown or unknowable risk. For instance, it is not known how many terrorist organizations there are in the world who would be tempted to commit such an act of sabotage. It is also not know what tools (e.g., armor-penetrating weapons) that they have at their disposal.

Risk from Direct Radiation of the Public from an Accident

This risk may come about in the highly unlikely event of accidental criticality.[17] Prevention of this type of accident is normally included in the storage system design and no criticality accident involving commercial spent fuel has ever occurred. However, if an accident were to occur and members of the public were near the fence boundary, a small dose of radiation may be received. Again, the absolute value of the risk to the public is extremely low and unquantifiable. That such a risk would exist to a small degree in fact may translate into a large risk from the public point of view.

Risk from Radioactive Releases During Normal Operation

Small amounts of radioactive material may be transported from the spent fuel into nearby air, soil and water during handling and storage. Under no circumstances is the risk from this process to be trivialized or disregarded, because it appears to be meaningful to the public. At a reactor site this release rate is included in the overall site release rate, which is dominated by normal reactor operations. At a large centralized storage facility the release rate would still be very small, but would account for 100% of the site's release rate.

Risk from Direct Radiation During Normal Operation

Radioactive material by definition releases radiation. When the radiation is in the form of gamma rays it has the ability to penetrate matter. Because the spent fuel is heavily shielded during normal operation and because the storage site's fence boundary is far from the source of radiation, an expert would not normally consider this risk to be significant. To many members of the public, however, such a risk is real. Therefore at the characterization stage, this risk must be included for consideration.

Risk of Theft of Nuclear Materials

For many who are involved in nuclear issues, the threat of theft of nuclear material ranks as one of the highest risks that we face with spent nuclear fuel. The most-often discussed motivation for theft is the desire of terrorist groups to construct a crude nuclear weapon from the ~1% plutonium content. Separation of the plutonium and manufacture of the weapon would be a very formidable task because of the high radioactivity and the difficulty of the chemical separation. However, the spent fuel in itself could be used as a terrorist weapon.

This threat is different from the other four types of threat in that the potential victims are not necessarily those people who live near the storage site. Physical location of the facility is far less significant in this case. The stakeholders are essentially all the people in the world. The level of security of the facility determines the risk to the stakeholders.

Comparative Risk in Location

The risks as described above are generally very small and of a nature that is difficult to estimate or measure. No amount of analysis will answer the question of absolute risk in a satisfactory way because there are too many unknowns.

The saving grace in the categorization listed in Figure 1 is that *difference* in risk between boxes in the top row and the bottom row may be much easier to analyze and understand than the absolute magnitude of the risk. As was stated in the introduction, the same dry-cask storage method is to be used at reactor sites and at a centralized interim storage facility. Either facility will be designed so that any leakage from the cask is trapped by design before it can migrate to the environment. All casks are monitored for their integrity and safety using the same methods. The security methods and accounting methods before and after relocation will be similar.

At this point the two absolute risks can be collapsed into one comparative risk which describes the differences in risk between storage at the two locations. One need not assume that one location is at a reactor and the other is not at a reactor. It may be that someday there is a plan to consolidate fuel storage at one reactor site for a given utility that owns nuclear power plants at several sites. In general, however, most discussions now involve the movement of fuel away from a reactor site to a monitored retrievable storage (MRS) facility, sometimes called an AFR (Away-From Reactor) storage facility.

If we suppose that the current location is at a reactor site and the proposed new location is an MRS, the major difference between the two may well be simply in the proximity and pathway to nearby humans. Because nuclear power plants were built to provide electricity generally to large metropolitan areas, they are typically located within 10 to 30 miles of those areas. Because of the growth of suburbs, many people may be living near a given nuclear power plant. Power plants in general also require cooling water and are therefore located adjacent to large bodies of water or rivers. This may in general increase the ease of transport of water-soluble radionuclides if any were to escape the confines of the facility.

The latest proposed location for an MRS is at the DOE's Nevada test site, where nuclear weapons were assembled and tested above ground and underground for 30 years. The location is 100 miles northwest of Las Vegas, NV. There are essentially no suburbs north of Las Vegas, however, and the population density near the test site is very sparse. There has been no non-governmental human activity at the site for over 40 years. The surrounding area, which is an arid desert, also has a very low population density.

Comparative Risk in Transportation

Suppose for a moment that the spent reactor fuel posed less risk to the public as a whole per year of storage per ton of material in a new, centralized interim storage facility in Nevada. Does this warrant the construction of and transportation to the new site? Aside from cost considerations, it may be that the risks to the public from the transportation outweigh any risk improvement from the re-location itself. The risks from transportation both real and perceived were listed in the second row of Table 1.

Again, the possibility of sudden release of radioactive material in an accident probably causes the most public concern. Over the years there have been many spent fuel shipments by both truck and rail, and there have been some accidents. However, radioactive material has never been released. Concerns have been expressed in strong terms by state officials in the US and there have been demonstrations (in some cases violent) in connection with shipments of spent fuel within Europe and Japan.[18]

Because the idea of comparative risk succeeded in improving the understanding of the storage risk, it is desirable to translate the transportation risk into a comparative risk as well. This is less obvious but also straightforward. It is to be realized that in no case the storage of spent fuel at reactor sites to be considered permanent - it will eventually be transported to a permanent disposal facility such as Yucca Mountain, NV. In fact Yucca Mountain is the only site under consideration for a permanent facility at this time. The characterization of the site has not been completed and it is certainly not ready to accept spent fuel for at least another two decades. But eventually the plan is to send all the spent fuel in the US to the Yucca Mountain site over a period of 23 years.

As stated above, the proposed location for the MRS is at the Nevada test site, which is where the entrance to the Yucca Mountain repository is planned to be. In other words, transportation of a given amount of spent fuel to the currently-proposed MRS entails essentially the same transportation route as to the final resting place of the fuel. Placing the

MRS at the entrance to the repository eliminates the need for a second re-location of the fuel in the future.

The rational question then is whether there is any difference in risk (real or perceived) in the transportation of the spent fuel to an interim storage facility over the next few decades versus directly to national repository when that repository opens, if the two are colocated.

Collapsing the 15 Risks into 4 Comparative Risks

The risks (both real and perceived) shown in Table 1 are collapsed in the following manner. The risk to the public *during storage* from radioactive material releases and direct radiation from non-accident conditions, accident conditions and sabotage (first 4 columns) are combined and evaluated on a comparative basis only. To the list of 15 risks we add another 5 risks that were not at first included. That is, the 5 risks during transportation to the National Repository from where it is stored (either the reactor sites or the MRS). The risk to the public *during transportation* from radioactive material releases and direct radiation from non-accident conditions, accident conditions and sabotage (first 4 columns) are combined and evaluated on a comparative basis only. The risk of theft is also converted into a comparative risk but is kept separate because the stakeholders are not the same. The results are shown in Table 2 below.

Table 2. The risks to the public from spent nuclear fuel re-location re-stated in terms of difference in risk (or comparative risk).

1. The difference in risk to the public during storage from radioactive material releases and direct radiation in non-accident and accident conditions or by sabotage (at-reactor dry storage vs. away-from-reactor dry storage or MRS).	2. The risk to the public from radioactive material theft during storage (at-reactor dry storage vs. away-from-reactor dry storage or MRS).
3. The difference in risk to the public during transportation from radioactive material releases and direct radiation in non-accident and accident conditions or by sabotage (transportation in the near-term to an MRS vs. transportation later to a National Repository).	4. The risk to the public from radioactive material theft during transportation (transportation in the near-term to an MRS vs. transportation later to a National Repository).

Restating the risks in this manner should keep the analysis and deliberations more focused on the real issues. That is not to say that the answer has become obvious now that the picture has been made more clear. The answer may depend on the specific reactor site and in the national policy in choosing an interim storage location. It will also depend on whether the citizens of Nevada are compensated adequately for the added risk they endure for the sake of the citizens of the 46 states that currently store spent nuclear fuel.

Analysis/Deliberation of Table 2 Comparative Risks

The analysis and deliberation of the comparative risks in Table 2 will not be straightforward because changing public perception of the risk is an integral part of the analytical/deliberation process. However, it is without question a simpler task than performing the same procedure with the risks listed in Table 1. Each of the four comparative risks is briefly analyzed in the next few paragraphs. This is not meant as an analysis or a deliberation, rather a prediction of where the process will lead.

It is also important to remember the distinction between analysis and analysis/deliberation. Pure risk analysis, as it has been employed in the past, has led to the conclusion that none of these risks are of significant consequence.[19]

Risk 1

This is the item that often gets the most attention in discussions. "Is the public health and safety radiation risk as a whole improved after the spent fuel is relocated?" When the fuel is moved to a location that is on the average more remotely located than where it is now, the answer will be yes, all other things being equal. Whatever risk there is from the spent fuel, through leakage, accident, or sabotage, the consequences are less where there are fewer people. This may not appeal to the state which hosts the MRS, but the population numbers will also be reflected in the number of votes in the US House of Representatives. In other words, the new site may have less risk exclusively because it has fewer people. It also has fewer votes in Congress to oppose the re-location. It seems likely that if Risk 1 were the only risk, an MRS facility would already be in use somewhere in the US.

Risk 2

This comparative risk is a function not strongly of location, but rather of the strength of the security at the new facility vs. the reactor sites. Polling organizations have found that there is public support for a centralized facility as being safer than the ~110 reactors sites in terms of security. At a factual level, a potential thief who wished to steal only a few fuel assemblies currently has the choice of ~110 sites to pick from. He then would select that site which had the weakest security. If the fuel were consolidated in a single facility that kept high security standards, it would very likely be more secure than the weakest of the 110 sites.[20] Again, it appears that Risk 2 alone points in the direction of the MRS.

Risk 3

Opposition to spent fuel transportation will not only occur in the state that is the host for the MRS (where there is a low population) but also in all the states that are along a transportation route. This will also include, ironically, any state from which the fuel is departing. At this point it is important to remember that we are considering only the *difference* in perceived risk between moving the fuel now or later. Will people perceive less risk 30 years in the future if the destination is a National Repository? Even when ignoring the lowered radiation levels in the future due to cooling, the answer to this question is probably yes. Additionally, deferring the transportation to a later date may be argued to be less risky if one were to discount the risk to present value, in the same manner as one were discounting future costs to present worth.

Risk 4

This risk is probably a real one, but when stated in terms of a comparative risk its effect becomes less important in the decision process than the other three. There will always be a risk of theft during transportation of spent fuel. Will the risk (real or perceived) be greater or less in the future? Cooling of the spent fuel over a 30 year period may make the fuel a more tempting target for thieves. However, there will be some changes in the plutonium isotopic composition (due to decay of ^{241}Pu with its 14 yr. half-life) that will make it less suitable for weapons. This may all wash out to a zero effect. However, as in the above case, deferring the transportation to some future date lowers the "present worth" of the risk.

Cost

As was mentioned above, the nuclear utilities in the US have contributed to the Nuclear Waste Fund at total of about $13 billion, which was to be used by the Federal Government for providing the infrastructure to accept spent fuel. Some of this money was originally to be spent on an MRS facility but no location for the facility was found.

If an MRS facility is not made available soon, the costs to the nuclear utilities across the country could be as high as $8 billion for the next 20 years and $1 - $3 billion per decade after that.[21] These costs are usually passed on to ratepayers.

The DOE has estimated that it will cost about $600 million to construct a centralized storage facility and approximately $250 million per year to operate it at full capacity, including the cost of transporting 2000 tons of spent fuel per year to the facility. Based on the DOE projections, the Congressional Budget Office estimated the MRS would cost $1.2 billion for the first 5 years altogether.[22] Based on these number a cost of $5 billion over 20 years is a reasonable cost estimate. This does not mean that storage as such a facility is necessarily cheaper than storage at a given reactor site.

Conclusions

In the characterization of risk in the public issue of relocation of spent nuclear fuel, pure analysis should not be used to discard any categories of risk prior to deliberation. Thus all issues that are viewed (by the stakeholders) to be risks are treated as risk until and unless resolved by analysis and deliberation.

The reduction of the spent-nuclear-fuel risk-categorization problem to 4 comparative risks is a useful transformation that may give greater efficiency the analytic/deliberation process.

It appears to this observer that the risks due to the first 2 categories of comparative risk (storage risks) are lessened by relocation of spent fuel to a remotely located, centralized interim storage facility. There are simply fewer people at the remote location to be harmed in the case of leakage or an accident. A single facility is also likely to be more secure from theft. Transportation risks, however, seem to be roughly the same whether the spent fuel is moved to a storage facility now or moved to a national repository some time in the future. This is true only if the storage facility is located immediately near the repository.

The greatest issue in spent fuel relocation is if transportation risks can rightly be discounted to present worth. If this is true, the present worth of the risk is greater for transportation to an MRS now than it is for transportation to the repository in the future. Whether the MRS facility reduces risk (discounted to present worth) may then depend on the discount rate.

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[1] Technical Bases for Yucca Mountain Standards Committee on Technical Bases for Yucca Mountain Standards, National Research Council ISBN 0-309-05289-0; 1995.
[2] Utilities, PUC's Agree Feds Must Solve SF Problem Now, Nuclear Waste News, January 30, 1997.
[3] Disposal and Storage of Spent Nuclear Fuel - Finding the Right Balance: A Report to Congress and the Secretary of Energy, Nuclear Waste Technical Review Board, March 1996.
[4] The Universal MPC System: The Evolution of NAC Spent Fuel Technology, W. B. Lee and D. Walker, Radwaste Magazine, Vol. 4, September 1997.
[5] Understanding Risk: Informing Decisions in a Democratic Society Paul C. Stern and Harvey V. Fineberg, Editors; Committee on Risk Characterization, National Research Council, 1996.

[6] Rethinking High-Level Radioactive Waste Disposal: A Position Statement of the Board on Radioactive Waste Management, National Academy Press, Washington, DC July 1990.
[7] Nuclear Imperatives and Public Trust: Dealing with Radioactive Waste, Luther Carter, Resources for The Future, 1987.
[8] Contracting Officer's Preliminary Determination that the Department of Energy's Delay in Beginning Spent Fuel Was Unavoidable, attachment to a letter from DOE headquarters to the nation's nuclear utilities, dated June 3, 1997.
[9] The Costs of Prolonging the Status Quo, Kris Sanda, Radwaste Magazine, May 1997.
[10] In a June 6, 1997 filing, 43 utilities and 46 state agencies asked the US Court of Appeals for the District of Columbia to compel DOE to accept spent nuclear fuel beginning Jan. 31, 1998. Nuclear Waste News, June 26, 1997.
[11] The MRS and the Mescalero Apaches, Fred Peso, Radwaste Magazine, Vol. 1, April 1994.
[12] Communicating Safety Every Step of The Way: What We Have Learned from The Public, Ann S. Bisconti, Radwaste Magazine, Vol. 4, Sept. 1997.
[13] Explosive Properties of Reactor-Grade Plutonium, J. Carson Mark, Science and Global Security, Vol. 4, 1993, page 111-128.
[14] Nuclear Power Issues and Choices, Report of the Nuclear Energy Policy Study Group, Spurgeon M. Keeney, Jr., Chrmn., Ballinger Publishing Company, Cambridge, Massechusetts, 1977.
[15] Interview with Michael McCloskey, then-chairman of the Sierra Club, by Luther J. Carter, October 1986. This interview is described in Ref. 7.
[16] Transmutation is one example of a technology that could eliminate the eventual need for transportation or disposal of the spent fuel. See, e.g., Nuclear Energy Generation and Waste Transmutation Using An Accelerator-Driven Intense Thermal Neutron Source, C. D. Bowman, et al, Nuclear Instruments and Methods in Physics Research, A320 (1992) pg. 336.
[17] A Review of Criticality Accidents, W. R. Stratton, Revised by D. R. Smith, NOE/NCT-04, Nuclear Criticality Information System, US Department of Energy Office of Safety Appraisals, March 1989.
[18] Transportation of Spent Fuel From Reactors to DOE Storage/Disposal Facilities - A Parametric Study, E. R. Johnson and P. M . Saverot, Radwaste Magazine, September 1997.
[19] Disposal and Storage of Spent Nuclear Fuel - Finding the Right Balance: A Report to Congress and the Secretary of Energy, Nuclear Waste Technical Review Board, March 1996, and references therein.
[20] R. L. Garwin, private communication.
[21] The Costs of Prolonging the Status Quo, Kris Sanda, Radwaste Magazine, May 1997.
[22] Disposal and Storage of Spent Nuclear Fuel - Finding the Right Balance: A Report to Congress and the Secretary of Energy, Nuclear Waste Technical Review Board, March 1996. page 26.